NASA Global Water-Cycle Research and the Water and Energy Cycle Research (WatER) Initiative

- **Chair:**
  - Professor Rafael Bras, MIT
- **NASA HQ:**
  - Dr. Jared Entin
- **Scientific Coordinators (GSFC):**
  - Dr. C. Adam Schlosser
  - Dr. Paul Houser
- **Program Assistant:**
  - Debbie Belvedere

Integrating Objective

To advance integrating models of the water and energy cycles at global scales that can predict variations in precipitation and hydrologic variables and exploit improved observations of precipitation, evaporation and the land hydrologic state.

Scientific Planning Task Force

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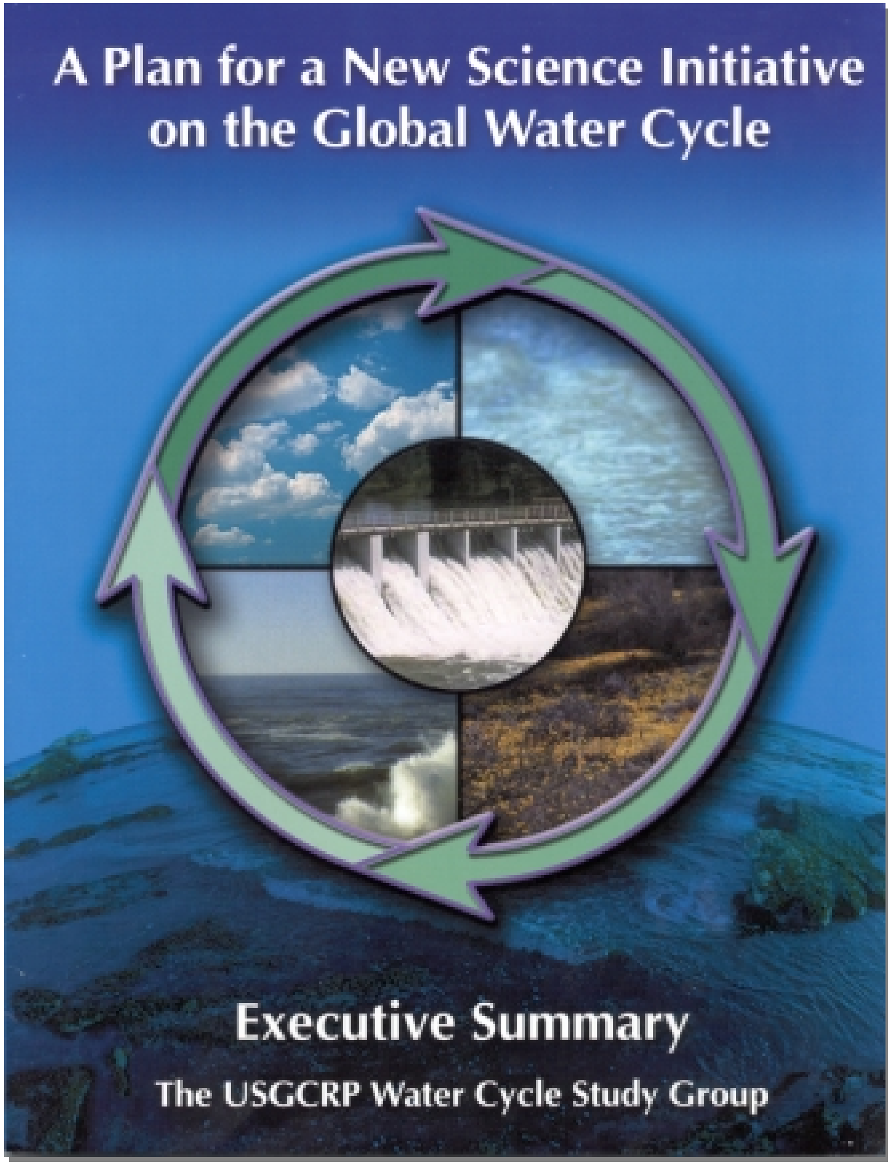
Starr, Dr. David

Planning Activities

- Publication of the ESE Research Strategy for 2000-2010 (Dec., 2000)
- Establish scientific planning mechanisms for the Global Water Initiative (March, 2001)
- AGU Town-Hall Meeting (May, 2001)
- First meeting of WatER Planning Task Force (July, 2001)
- First GWEC NRA approvals (September, 2001)
- Second meeting of the WatER Planning Task Force (Nov., 2001)
- AGU/AMS Town-Hall Meetings (December, 2001 & January, 2002)
- NASA Water-Cycle Research Workshop (January, 2003)
- WatER Initiative Document* Release (February, 2003)

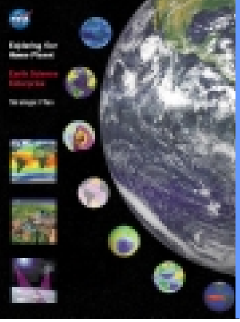
*Status of WatER Document:
Chapter detailing the Implementation Strategy in final draft stage

USGCRP Scientific Mandate to Study the Global Water Cycle



Main Science Questions

- What are the causes of water cycle variations on both global and regional scales, and to what extent are these variations induced by human activity?
- To what extent are variations in the global and regional water cycle predictable?
- How are water and nutrient cycles linked in terrestrial and freshwater ecosystems?



NASA Earth Science Enterprise:
Studying Climate Change and Its Impacts

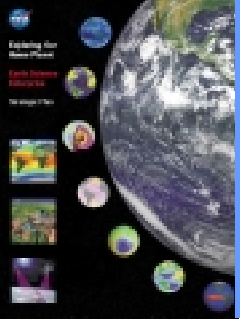
__V1__: How are global precipitation, evaporation and the cycling of water changing?

__R1__: What are the effects of clouds and surface hydrologic processes on Earth's climate?

__R2__: How do ecosystems response to and affect global environmental change and the carbon cycle?

__C1__: How are variations in local weather, precipitation and water resources related to global climate variation?

__P1__: How can weather forecast reliability be improved by new space-based observations, data assimilation and modeling?



NASA Earth Science Enterprise:
Studying Climate Change and Its Impacts

How is the Earth changing and what are the consequences for life on Earth?

Variability: How is the global Earth system changing?

V1: How are global precipitation, evaporation and the cycling of water changing?

V2: How is the global ocean circulation varying on interannual, decadal, and longer time scales?

V3: How are global ecosystems changing?

V4: How is stratospheric ozone changing, as the abundance of ozone-destroying chemicals decreases and new substitutes increase?

V5: What changes are occurring in the mas of the Earth's ice cover?

Forcing: What are the primary forcings of the Earth system?

F1: What trends in atmospheric constituents and solar radiation are driving global climate?

Response: How does the Earth system response to natural and human-induced changes?

R1: What are the effects of clouds and surface hydrologic processes on Earth's climate?

R2: How do ecosystems response to and affect global environmental change and the carbon cycle?

R3: How can climate variations induce changes in the global ocean circulation?

Consequences: What are the consequences of change in the Earth system for human civilization?

C1: How are variations in local weather, precipitation and water resources related to global climate variation?

C2: What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity?

C3: What are the consequences of climate and sea level changes and increased human activities on coastal regions?

Prediction: How well can we predict future changes in the Earth system?

P1: How can weather forecast reliability be improved by new space-based observations, data assimilation and modeling?

P2: How well can transient climate variations be understood and predicted?

P3: How well can long-term climatic trends be assessed or predicted?

P4: How well can future atmospheric chemical impact on ozone and climate be predicted?

P5: How well can cycling of carbon through the Earth system be modeled, and how reliable are predictions of future atmospheric concentrations of carbon dioxide and methane by these models?

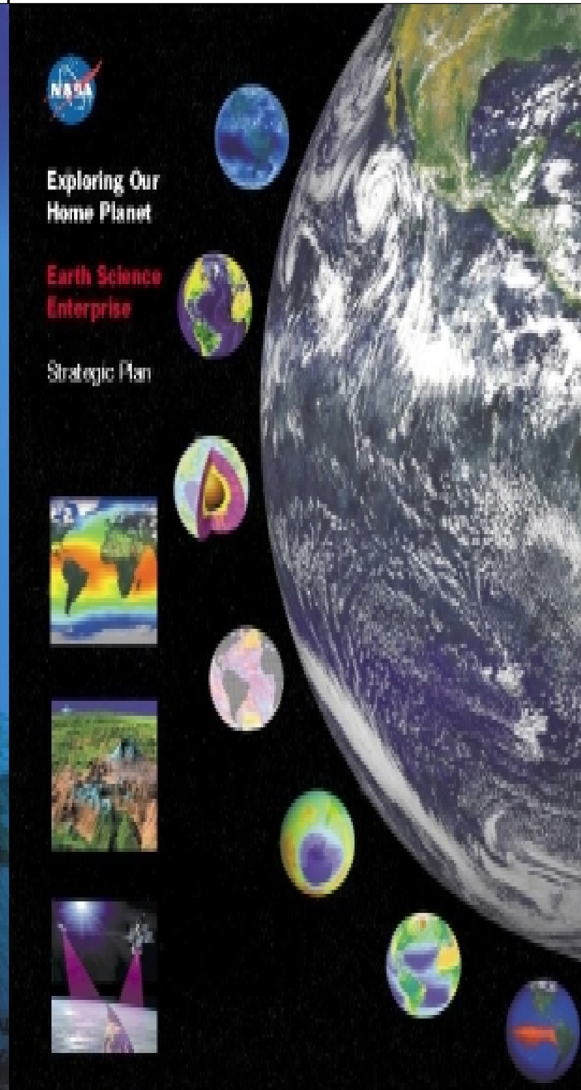
Mapping the WatER Science Questions/Goals

USGCRP	NASA ESE	WatER
Variability Quantify variability in the water cycle.	**Variability** How are global precipitation, evaporation and the cycling of water changing? (***V1***)	**Variability** **What are the trends and variability in precipitation and soil-moisture storage elements of the water and energy cycles?**
Understand the underlying mechanisms of variability. Distinguish human-induced and natural variations.	**Responses** What are the effects of clouds and hydrologic processes on global climate? (***R1***)	**Fluxes and Feedbacks** **How can the key pathways of water and energy in the atmosphere and between the atmosphere and the Earth surface be quantified? How are these pathways influenced by observed or projected climate change?**
Predictability Quantify the predictability of variations in the water cycle.	**Predictability** How are variations in weather, precipitation, and water resources related to global climate change? (***C1***)	**Predictability** **What are the limits of predictability of precipitation, soil moisture, and other hydrologic variables under a variety of climate conditions and transient climatic anomalies?**
Link to Biogeochemistry Determine links between water, carbon, nitrogen, and other nutrients in terrestrial and fresh water ecosystems.	**Link to Biogeochemistry** How do ecosystems respond to, and affect global environmental change and the carbon cycle? (***R2***)	**Link to Biochemistry** **What are the mechanisms and the time-scales of interactions between terrain, soil, vegetation, precipitation and hydrologic processes? What are the processes that link the water, energy and carbon cycles?**
Enabling Prediction Improve predictions of water resources by quantifying fluxes between water reservoirs.	**Enabling Prediction** How can weather forecasts be improved by new space-based observations, data assimilation, and modeling? (***P1***)	**Enabling Prediction** **How can climate and weather forecasts be improved by incorporating new global observations of precipitation, soil moisture and other hydrologic variables? How can data assimilation methods improve initial conditions and the formulation of models?**

Mapping the WatER Science Questions/Goals

USGCRP

NASA ESE



WatER

Variability
What are the trends and variability in precipitation and soil-moisture storage elements of the water and energy cycles?

Fluxes and Feedbacks
How can the key pathways of water and energy in the atmosphere and between the atmosphere and the Earth surface be quantified? How are these pathways influenced by observed or projected climate change?

Predictability
What are the limits of predictability of precipitation, soil moisture, and other hydrologic variables under a variety of climate conditions and transient climatic anomalies?

Link to Biochemistry
What are the mechanisms and the time-scales of interactions between terrain, soil, vegetation, precipitation and hydrologic processes? What are the processes that link the water, energy and carbon cycles?

Enabling Prediction
How can climate and weather forecasts be improved by incorporating new global observations of precipitation, soil moisture and other hydrologic variables? How can data assimilation methods improve initial conditions and the formulation of models?

Mapping the WatER Science Questions/Goals

Variability

What are the trends and variability in the precipitation and the soil-moisture storage elements of the water and energy cycles?

Fluxes and Feedbacks

How can the key pathways of water and energy within the atmosphere and between the atmosphere and the Earth surface be quantified? How are these pathways influenced by observed or projected climate changes?

Link to Biochemistry

What are the mechanisms and the time-scales of interactions between terrain, soil, vegetation, precipitation and hydrology? What are the processes that link the water, energy and carbon cycles?

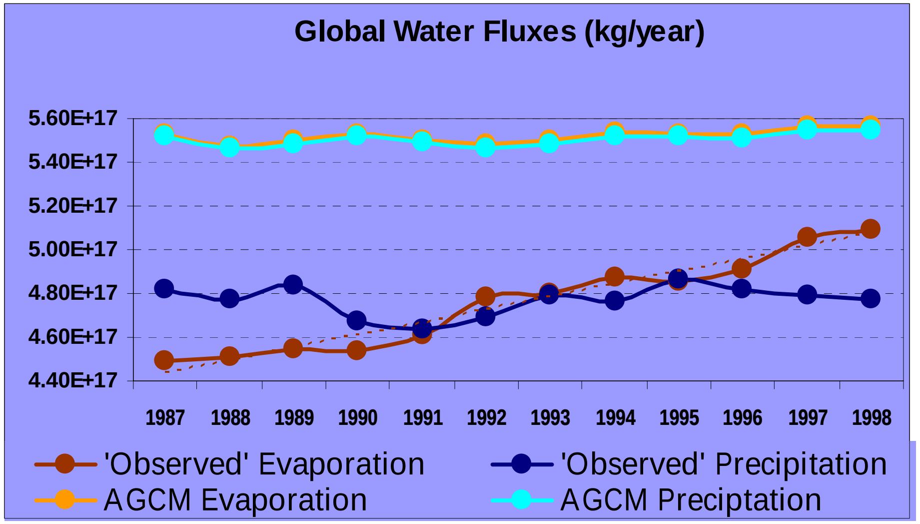
Predictability

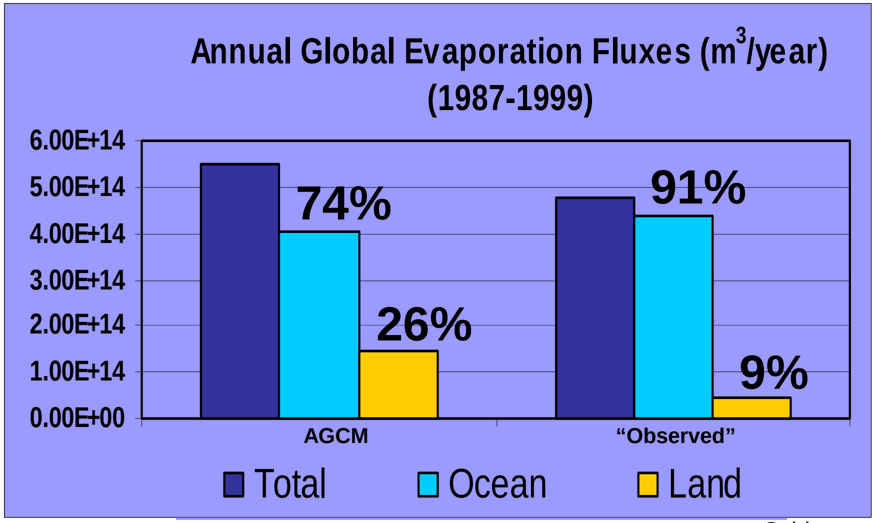
What are the limits of predictability of precipitation, soil moisture, and other hydrologic variables under a variety of climate conditions or transient climatic anomalies?

Enabling Improved Prediction

How can climate and weather forecasts be improved by incorporating new global observations of clouds, precipitation and soil moisture? How can data assimilation methods improve initial conditions and the formulation of models?

Water-Cycle Science Issues: Precipitation and Evaporation





Schlosser

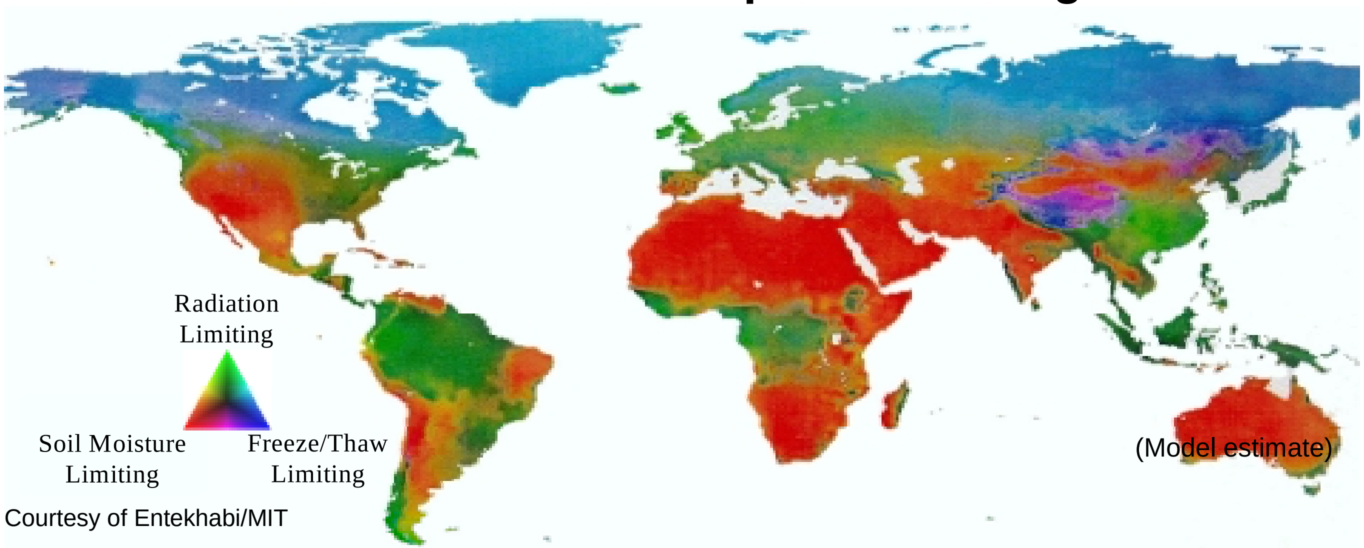
- Observed averaged annual evaporation and precipitation mass flux balance to within 1%.
  - However, interannual global variations considerably uncorrelated.

- AGCM mean "rate" of annual global water cycle exceeds observed (~15%).
- AGCM interannual variability of annual global precip/evap ~50%/35% lower than observed.
- Relative contributions of land and ocean fluxes differ considerably.
  - What are the sources of these discrepancies (both in the models and "observations")?

- Trend in "observed" global evaporation (~1 %/year), but no trend in precipitation.
- Trend in AGCM global water-cycle rate during 1987-1999 and order of magnitude smaller.
  - Source of modeled trend from prescribed SSTs, is the response accurate?
  - Observations insufficient to detect AGCM trend (e.g. Ziegler et al., 2002).

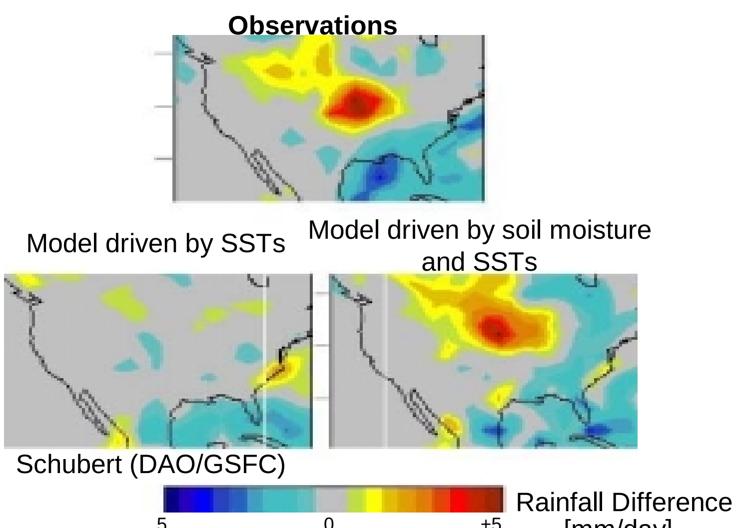
Water-Cycle Science Issues:
Land Hydrologic State

Control of land-atmosphere exchanges

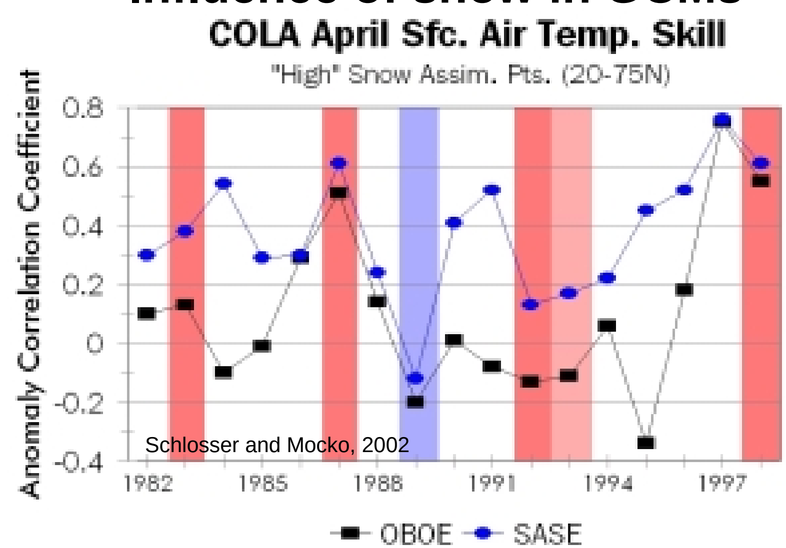


Influence of soil moisture in a GCM

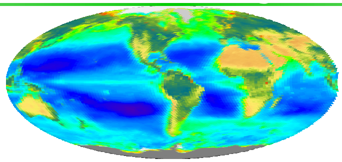
Summer 1993 Rainfall Minus Summer 1988 Rainfall



Influence of snow in GCMs

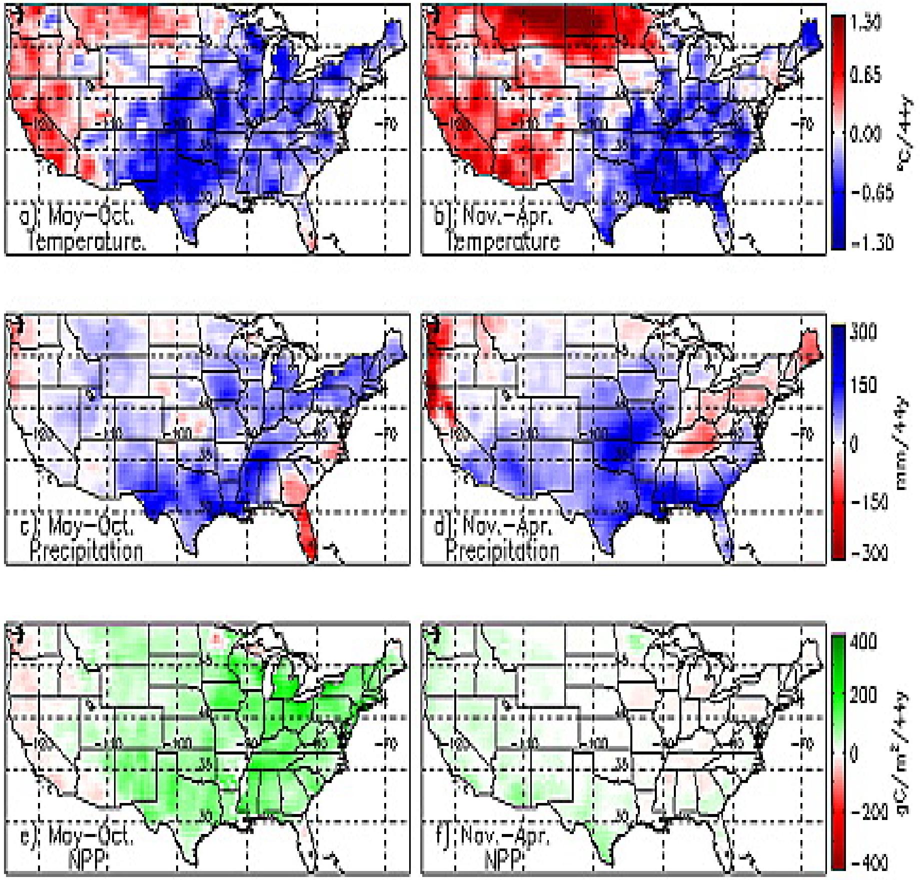


Links to Carbon Cycle

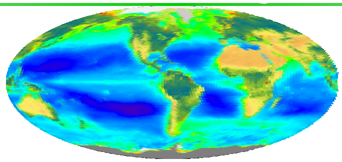


U.S. Global Change Research Program
Carbon Cycle Science Program
An Interagency Partnership

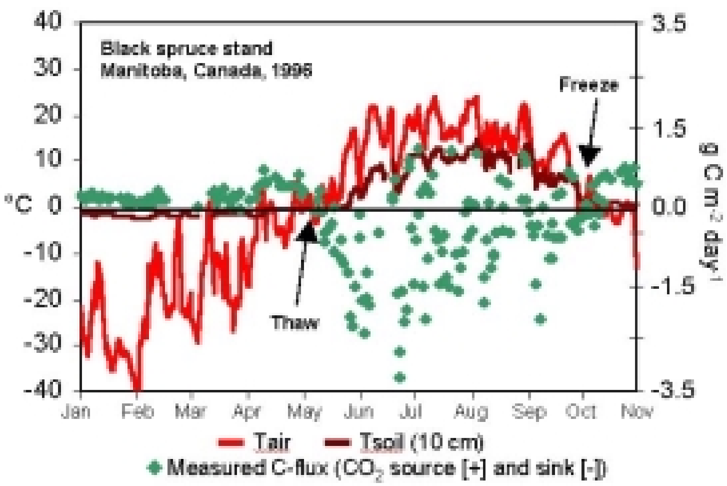
Nemani *et al.* (2002) demonstrate a robust relationship between carbon and water cycle trends

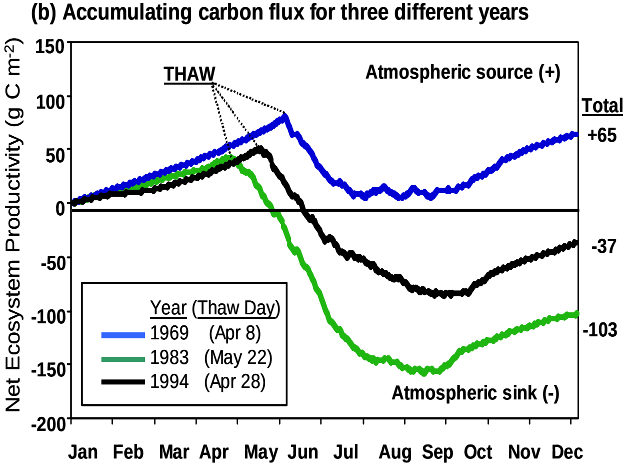


Links to Carbon Cycle



Landscape freeze/thaw dynamics drive boreal carbon balance.

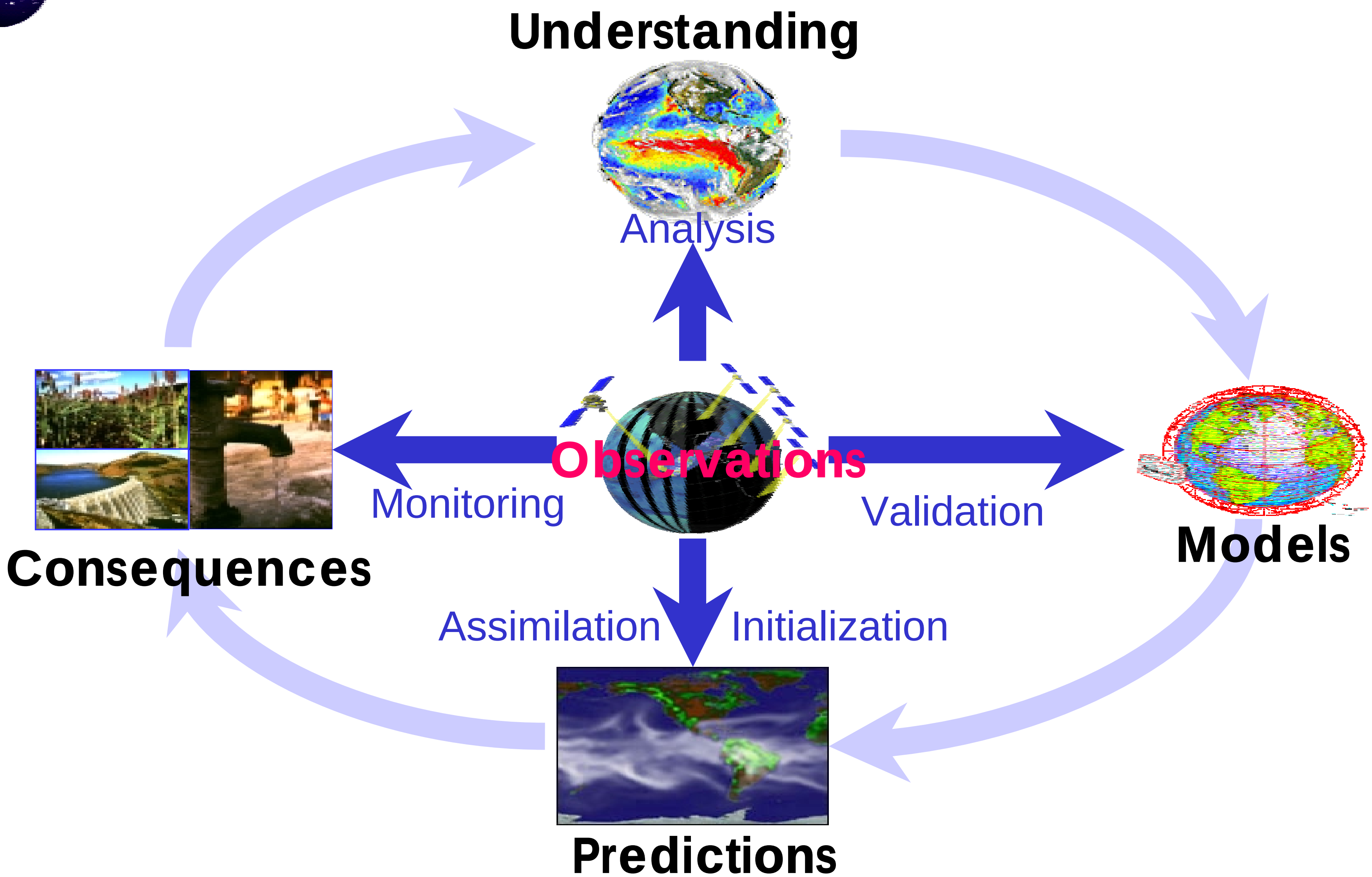




Frolking et al., 1996

Are Northern land masses sources or sinks for atmospheric carbon?

Water-Cycle Research : *From Observations to Consequences*

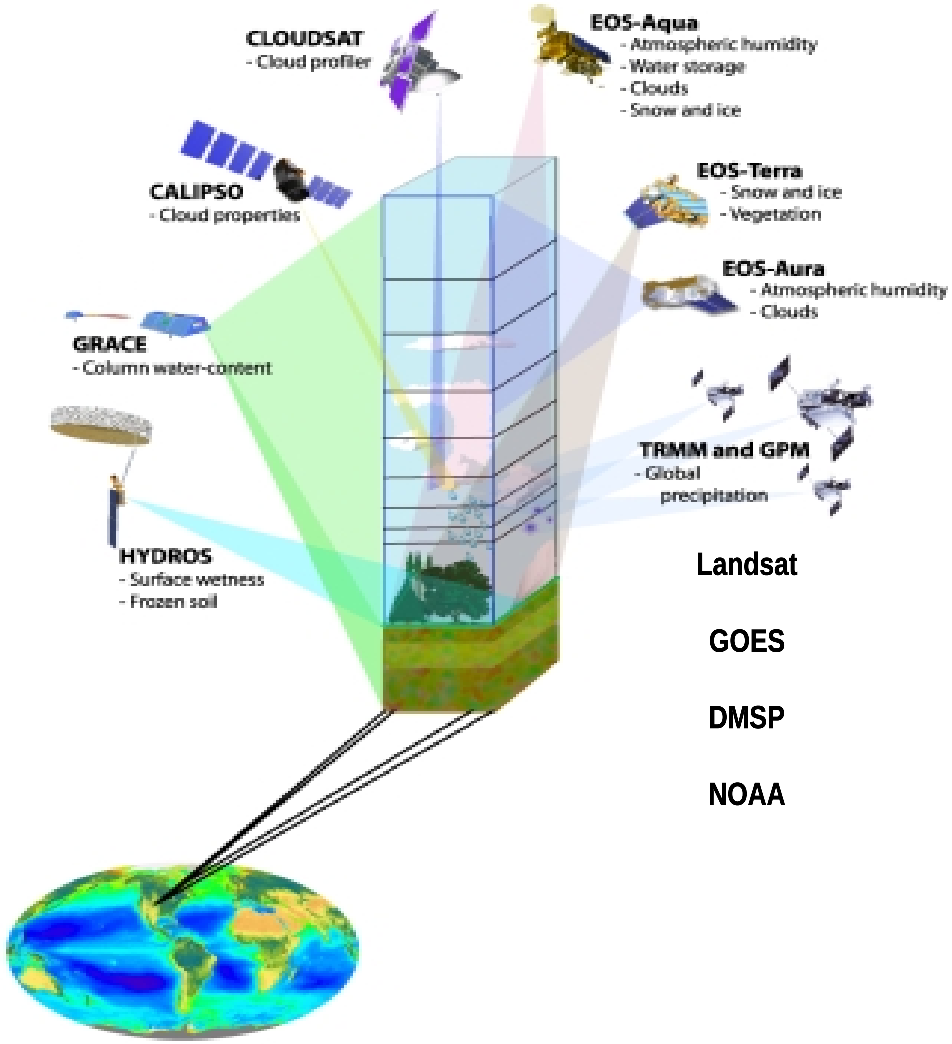


NASA is *the national space agency* and should exploit its unique capabilities for space-based observations to advance scientific understanding (i.e. research and development)

Global Water-Cycle Observation Strategy

Improve/nurture global measurements :

Precipitation (P), Evaporation (E), P-E and the land hydrologic state (soil water & freeze/thaw, and snow)

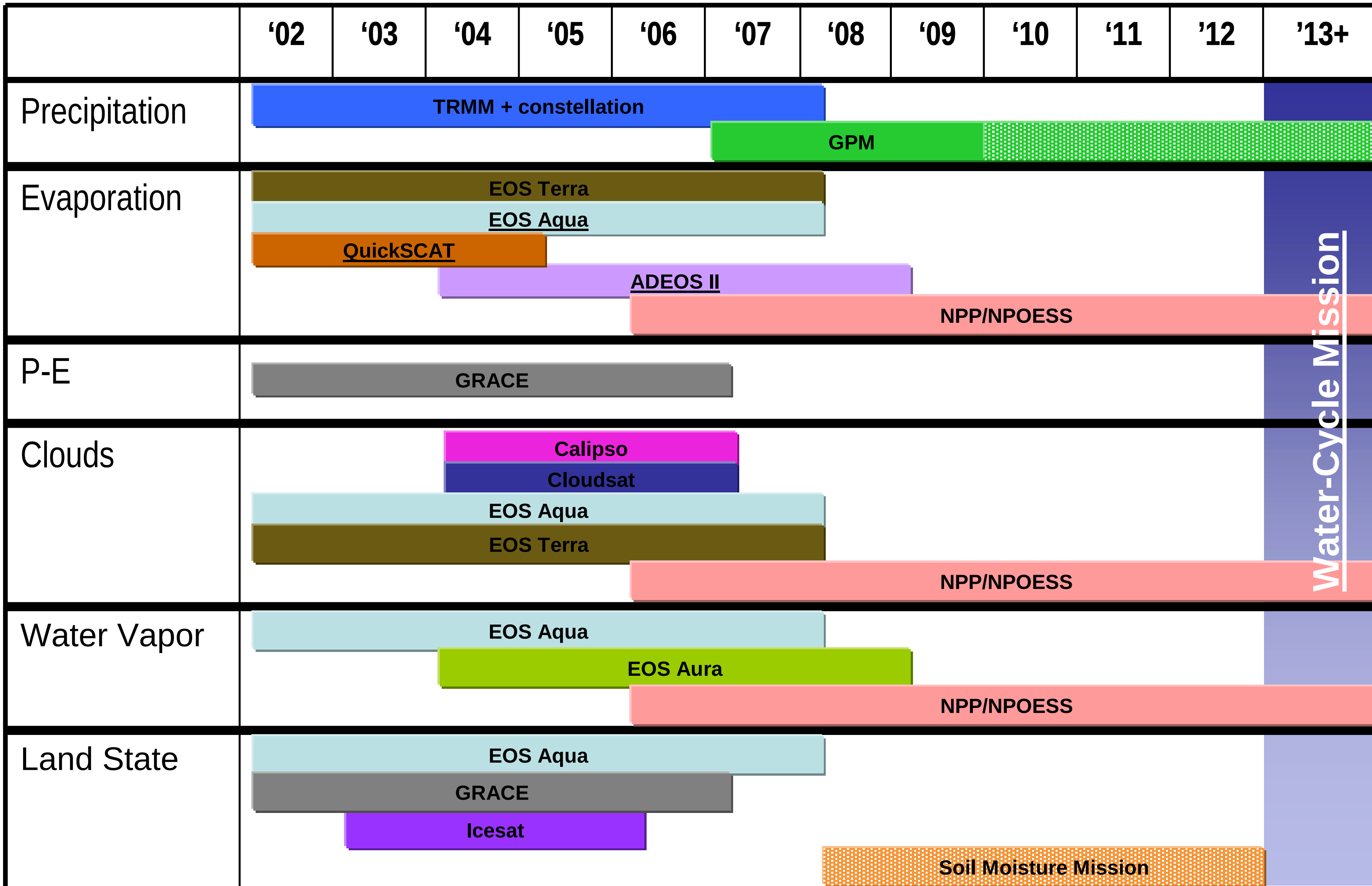


Future: *Water Cycle Mission*

Observation of water molecules through the atmosphere and land surface using an active/passive hyperspectral microwave instrument.

Quantity	Spatial Resolution	Temporal Resolution	Frequency
Groundwater	50 km	2 weeks	100 MHz?
Soil Moisture	10 km	3 days	1.4 GHz
Salinity	50 km	2 weeks	1.4 GH
Freeze/thaw	1 km	1 day	1.2 GHz
Rain	5 km	3 hour	10-90 GHz
Falling Snow	5 km	3 hour	150 GHz
Snow	1-5 km	1 day	10-90 GHz
TPW	10 km		
	(sea)	3 hour	6-37 GHz
	(land)	3 hour	183 GHz
Temperature	10 km		
	(sea)	3 hour	6-37 GHz
	(land)	3 hour	6-37 GHz
ET (4DDA)	5 km	3 hour	1.4-90 GHz

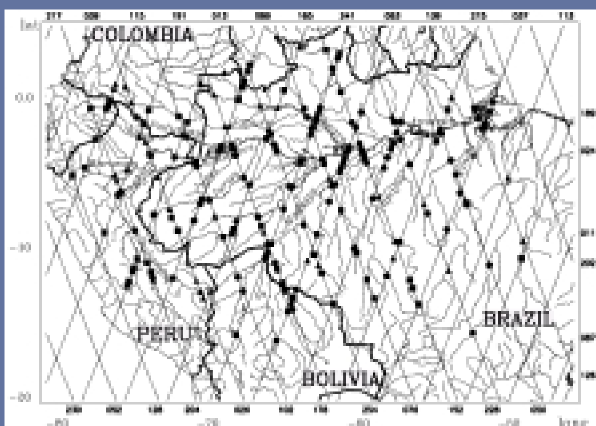
WatER Satellite Observation Timeline



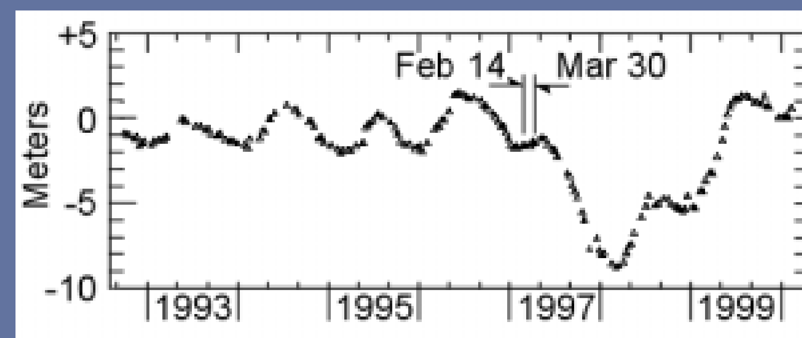
Global measurements of River Discharge

Water level measurements could be determined from
radar altimetry or **interferometric synthetic aperture radar**

Presently, radar altimeters are configured for oceanographic applications, thus lacking the spatial resolution that may be possible for rivers and wetlands.



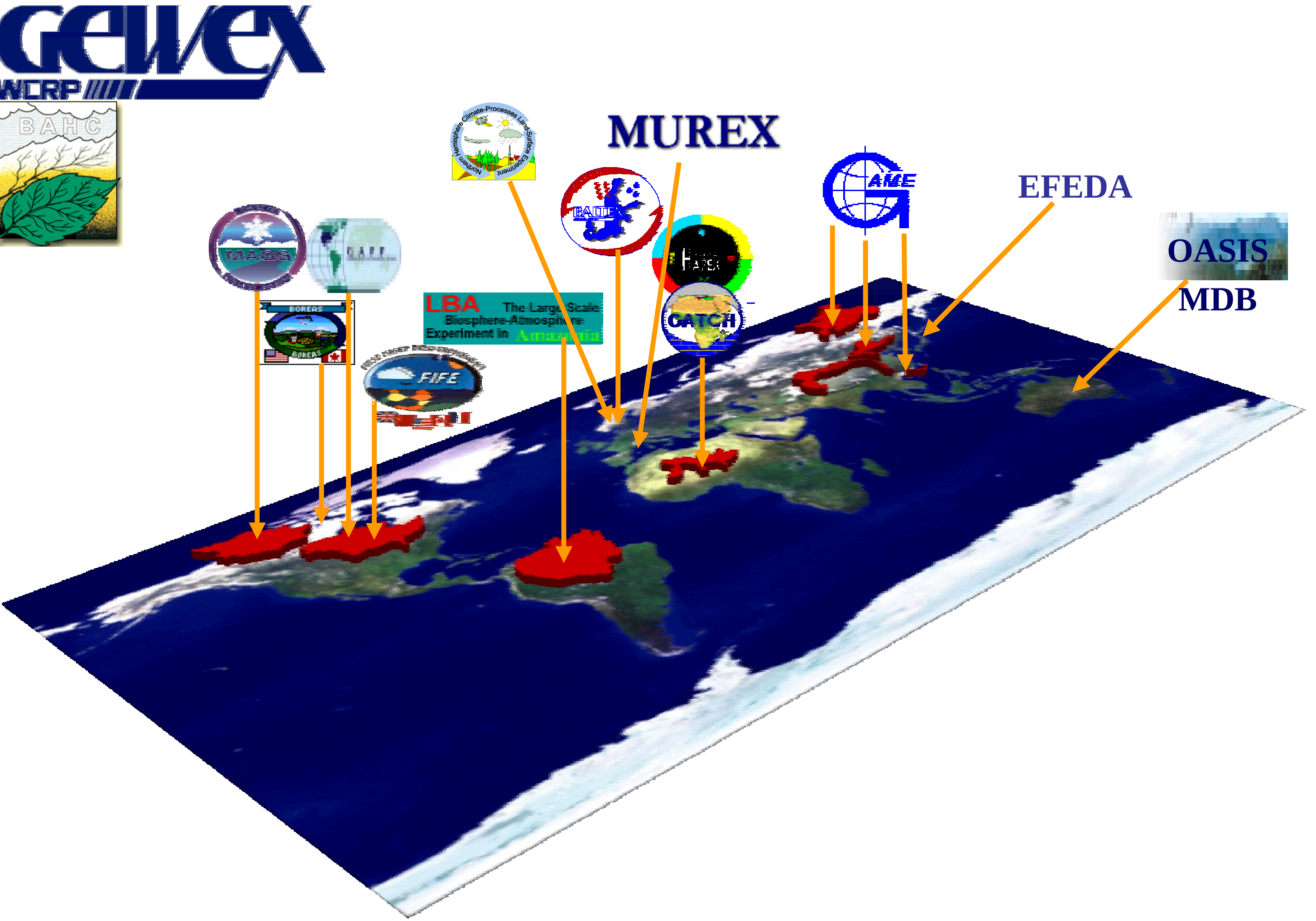
Topex/POSEIDON track. Circles indicate locations of water level changes measured by T/P radar altimetry over rivers and wetlands.

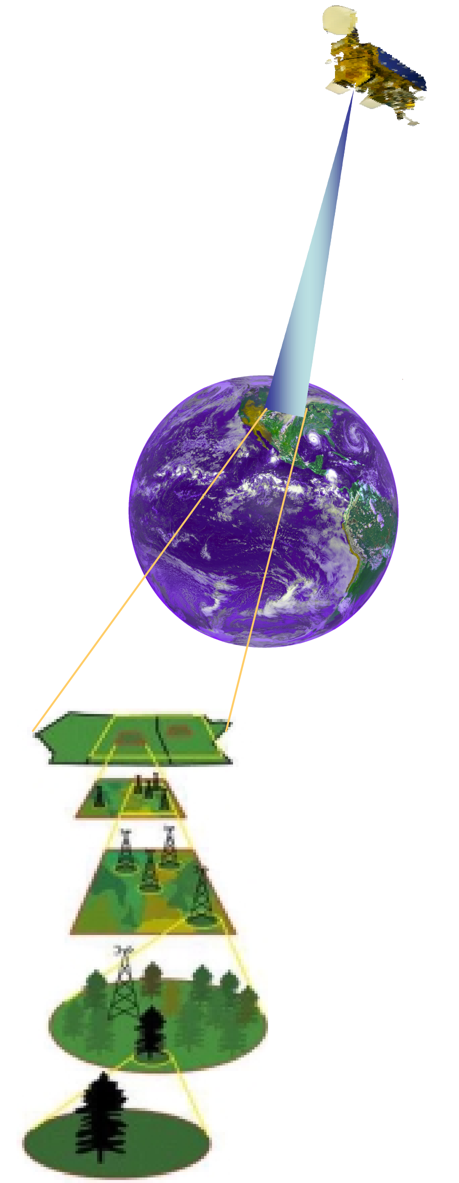


Water surface heights, derived from Topex/POSEIDON radar altimetry.

Because in-situ observations are incapable of describing the flow and storage change, NASA is working to determine appropriate satellite platforms that measure the flow and storage change.

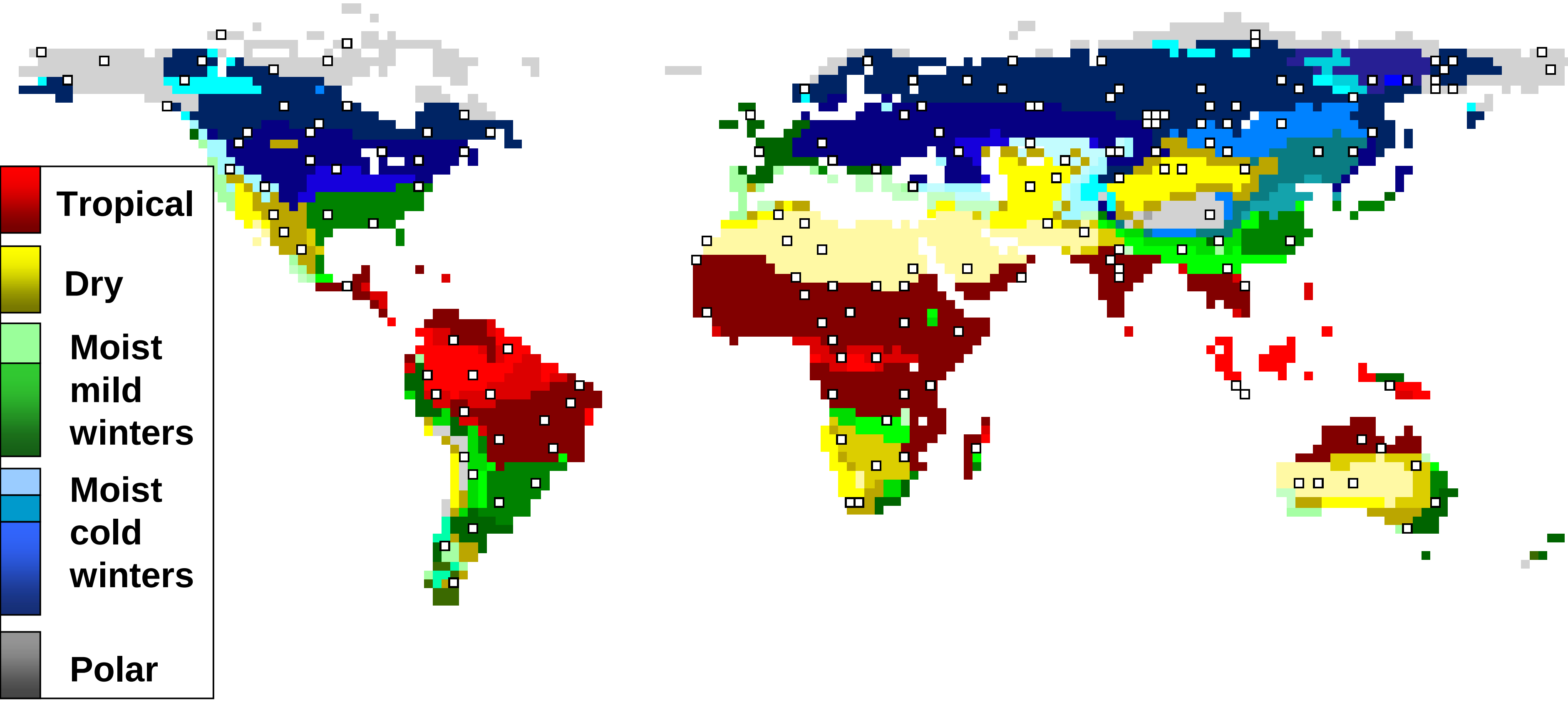
Partnerships with Large-scale Field Experiments





Support current and future field/basin studies to advance global scale calibration, validation, analysis and applications

Indicator basins to detect climate change



5% of the global grids are monitored
Optimization criteria is to match the mean and variability for P+E+Q

Modeling and Assimilation

Existing Climate Models

Integrated Global Observations:
Ground- and Space-Based Observing Programs

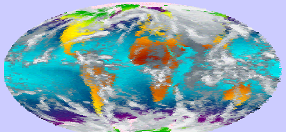
Advance Understanding and Model Physics

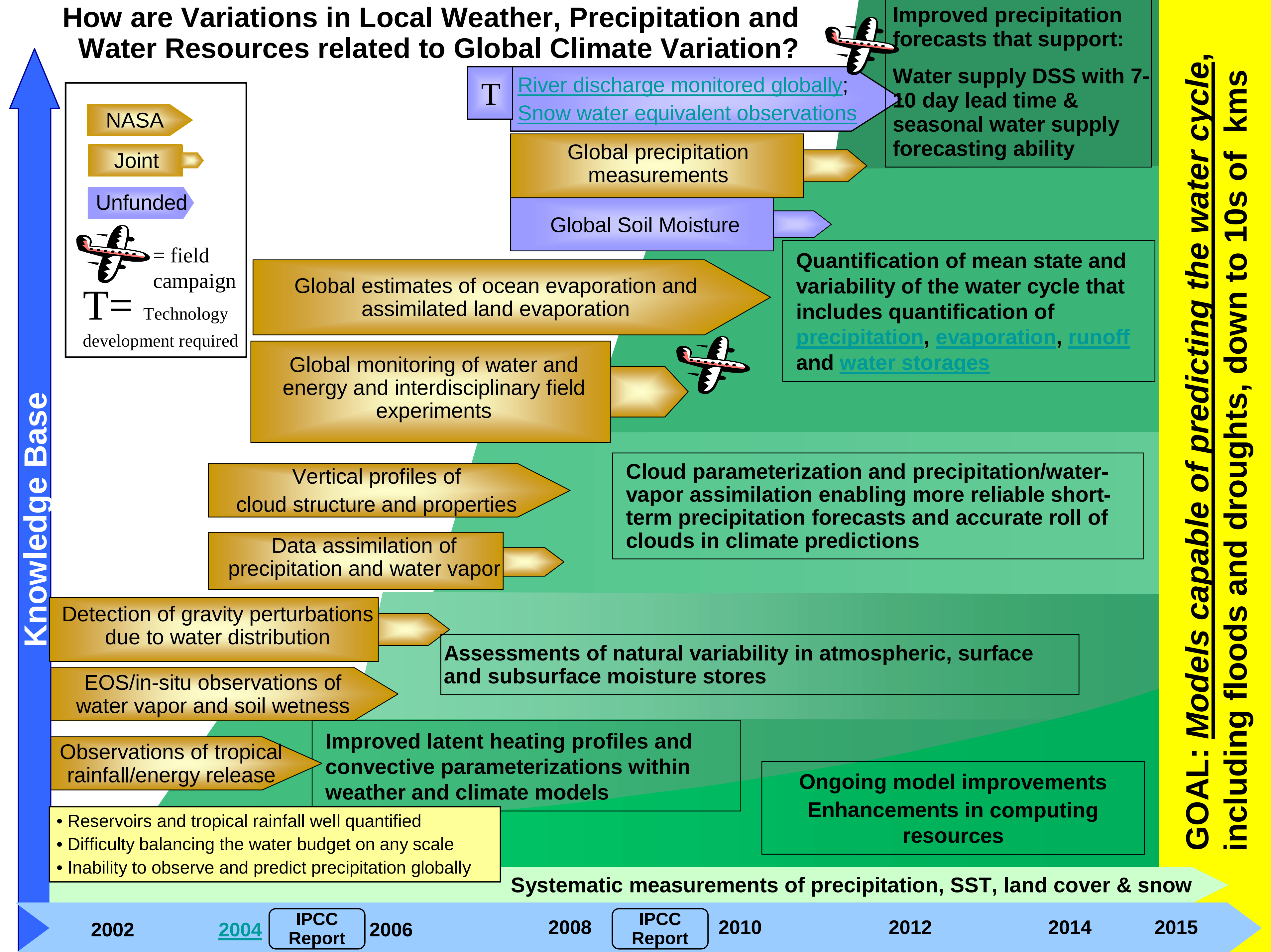
Improve Initialization & Assimilation

Diagnose and Identify Predictable Changes

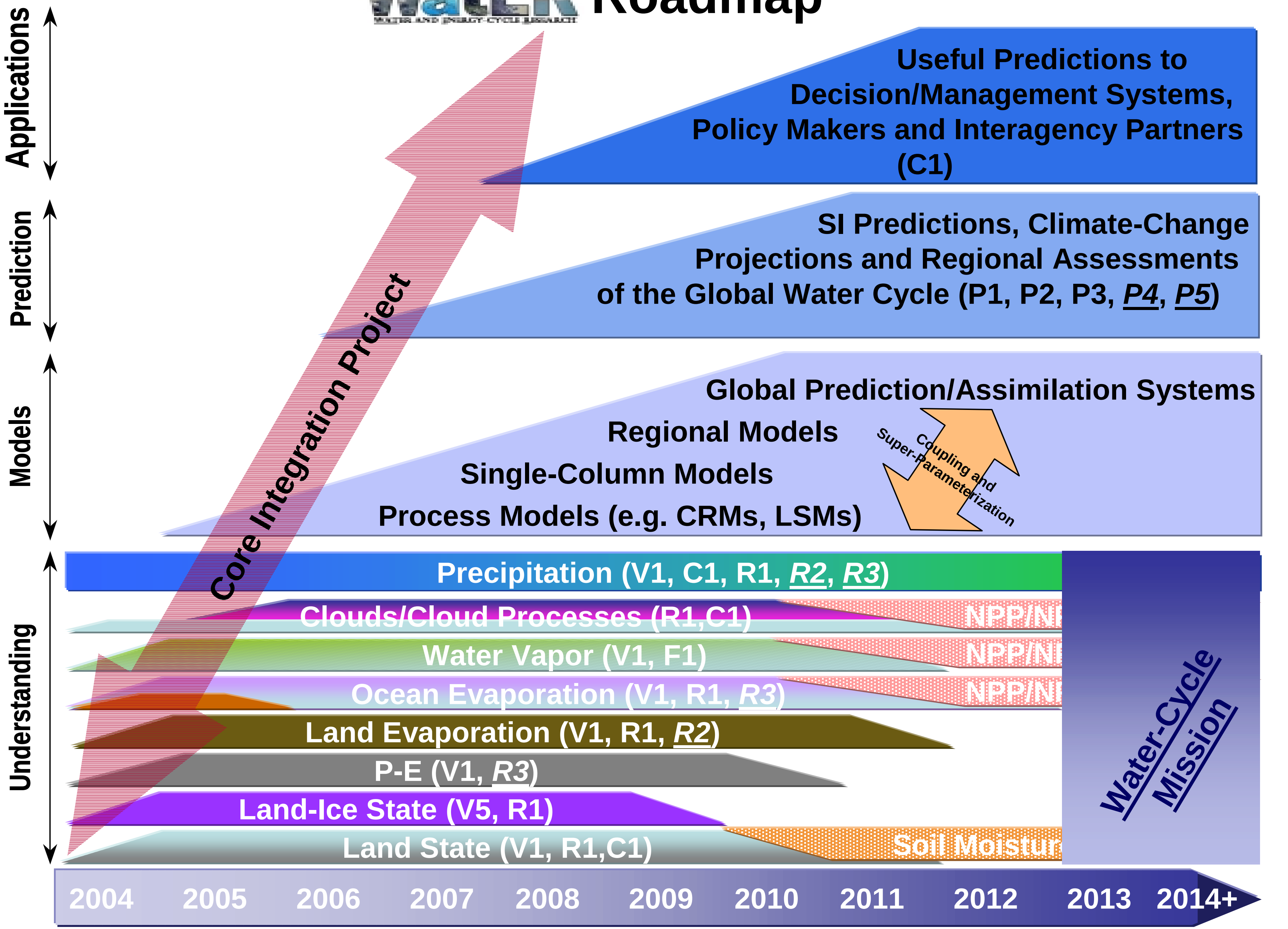
Next-generation Global Water-Cycle Prediction System

Water-cycle Prediction




How are Variations in Local Weather, Precipitation and Water Resources related to Global Climate Variation?
Knowledge Base
NASA
Joint
Unfunded
= field campaign
T= Technology development required
T
River discharge monitored globally; Snow water equivalent observations
Improved precipitation forecasts that support:
Water supply DSS with 7-10 day lead time & seasonal water supply forecasting ability
Global precipitation measurements
Global Soil Moisture
Global estimates of ocean evaporation and assimilated land evaporation
Quantification of mean state and variability of the water cycle that includes quantification of precipitation, evaporation, runoff and water storages
Global monitoring of water and energy and interdisciplinary field experiments
Vertical profiles of cloud structure and properties
Cloud parameterization and precipitation/water-vapor assimilation enabling more reliable short-term precipitation forecasts and accurate roll of clouds in climate predictions
Data assimilation of precipitation and water vapor
Detection of gravity perturbations due to water distribution
Assessments of natural variability in atmospheric, surface and subsurface moisture stores
EOS/in-situ observations of water vapor and soil wetness
Observations of tropical rainfall/energy release
Improved latent heating profiles and convective parameterizations within weather and climate models
Ongoing model improvements
Enhancements in computing resources
• Reservoirs and tropical rainfall well quantified
• Difficulty balancing the water budget on any scale
• Inability to observe and predict precipitation globally
Systematic measurements of precipitation, SST, land cover & snow
GOAL: Models capable of predicting the water cycle, including floods and droughts, down to 10s of kms
2002
2004
IPCC Report
2006
2008
IPCC Report
2010
2012
2014
2015

WatER Roadmap



Initiative Summary

- **Foster *advances in understanding* through EOS, ESSP and future NASA missions and international partnerships.**
- **Support *advances in model physics*.**
- **Instill *modeling/assimilation advances into prediction systems*.**
- **Foster *predictions that are "useful"* for novel application activities.**

Integrating objective

To advance integrating models of the water and energy cycles at global scales that can predict variations in precipitation and hydrologic variables and exploit improved observations of precipitation, evaporation and the land hydrologic state.